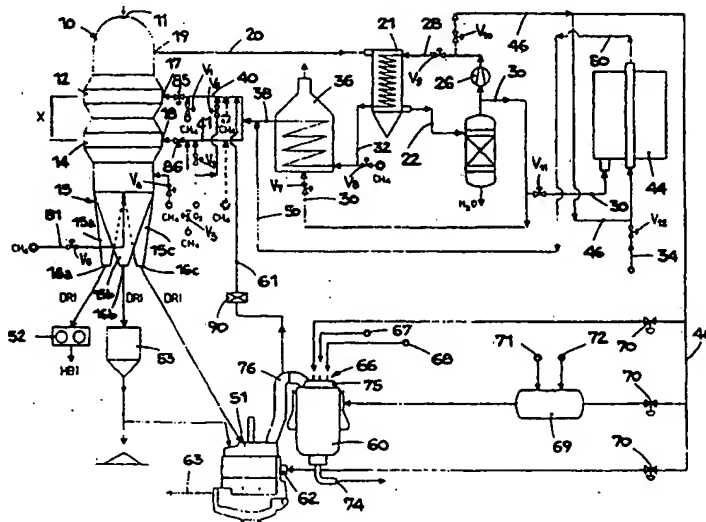


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b>  <b>C21B 13/14, 13/02, 13/04</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/36160</b>  <b>(43) International Publication Date:</b> 22 June 2000 (22.06.00)
<b>(21) International Application Number:</b> PCT/IB99/01924  <b>(22) International Filing Date:</b> 2 December 1999 (02.12.99)  <b>(30) Priority Data:</b> UD98A000215 11 December 1998 (11.12.98) IT  <b>(71) Applicant:</b> DANIELI & C. OFFICINE MECCANICHE SPA [IT/IT]; Via Nazionale, I-33042 Buttrio (IT).  <b>(72) Inventors:</b> BENEDETTI, Gianpietro; Strada degli Aceri, 32, I-33030 Campoformido (IT). PAVLICEVIC, Milorad; Via Pracchiuso, 31/7, I-33100 Udine (IT). MARTINIS, Alessandro; Via Gervasutta, 158, I-33100 Udine (IT). LOSCIALE, Matteo, Vittorio; Via Canada, 2f, I-33100 Udine (IT). RABASCALL, David; Urb. Roraima M5, 3, Puerto Ordaz (VE). BUENO, Henry, Rafael; Urb. Roraima M 9, 2, Puerto Ordaz (VE).  <b>(74) Agent:</b> PETRAZ, Gilberto; GLP Srl, Piazzale Cavedalis, 6/2, I-33100 Udine (IT).	<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>	

**(54) Title:** METHOD AND INTEGRATED PLANT FOR THE PRODUCTION OF STEEL BY MEANS OF DIRECT REDUCTION OR IRON OXIDES

**(57) Abstract**

Method and integrated plant for the production of steel starting from mineral iron, wherein the iron is present in the form of oxides, comprising the following steps and means for doing so: the mineral iron is fed into a vertical reduction furnace (10) of the type with a gravitational load; a mixture of high temperature gas is injected into the reduction furnace (10); the directly reduced iron (DRI) is removed from the reduction furnace (10), and the directly reduced iron (DRI) is melted in a melting furnace (51); the directly reduced iron (DRI) going to feed the melting furnace (51) directly and at least a part of the recircled gases of the reduction furnace (10) being used in a scrap pre-heating station (60) or as fuel for burners (62, 66) or directly introduced into the scrap pre-heating station (60).

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

## METHOD AND INTEGRATED PLANT FOR THE PRODUCTION OF STEEL BY MEANS OF DIRECT REDUCTION OR IRON OXIDES

\* \* \* \* \*

## FIELD OF THE INVENTION

5 This invention concerns a process to produce steel starting from mineral iron, wherein the iron is present in the form of oxides, and the relative plant which comprises a reduction furnace with multiple inlets for the reducing gas and inside which the process of direct reduction of the iron  
10 (DRI) is carried out. The lower outlet of the reduction furnace is of the multiple type to facilitate the selective and simultaneous discharge of several types of product, either hot or cold, so that it may be subsequently stored, sent to a melting furnace, for example of the electric arc  
15 type, to produce liquid steel, or converted into hot briquette iron (HBI). The exhaust gas from the reduction furnace is recircled and also used as fuel for the burners of the melting furnace or to heat the scrap in a pre-heating station.

## 20 BACKGROUND OF THE INVENTION

The state of the art includes processes of direct reduction which use the injection of hydrocarbons into the current of reducing gas to allow the reaction of reforming the methane in the furnace with the H<sub>2</sub>O and CO<sub>2</sub> in the gas;  
25 there are also known processes of direct reduction which use the injection of hydrocarbons with C>5 directly into the furnace in the zone between the injection of the reducing gas and the outlet from above of the burnt gas.

From the following patent documents other processes are  
30 known for the direct reduction of mineral iron:

US-A-2,189,260,	US-A-3,601,381,	US-A-3,748,120,
US-A-3,749,386,	US-A-3,764,123,	US-A-3,770,421,
US-A-3,816,101,	US-A-4,054,444,	US-A-4,046,557,

US-A-4,173,465, US-A-4,188,022, US-A-4,234,169,  
US-A-4,201,571, US-A-4,270,739, US-A-4,536,213,  
US-A-4,374,585, US-A-4,528,030, US-A-4,556,417,  
US-A-4,720,299, US-A-4,752,329, US-A-4,900,356,  
5 US-A-5,064,467, US-A-5,078,788, US-A-5,387,274,  
and US-A-5,407,460.

The state of the art also includes processes wherein the hot metallic iron is produced in a reduction furnace of the shaft type, with a vertical and gravitational flow of the material, which is subsequently sent to the melting furnace by means of a closed pneumatic transport system in an inert atmosphere.

#### SUMMARY OF THE INVENTION

The method to produce steel starting from metallic iron obtained by the direct reduction of iron oxides and the relative plant according to the invention are set forth and characterised in the respective main claims, while the dependent claims describe other innovative features of the invention.

20 The method according to the invention consists of an integrated process of direct reduction of the iron oxides and the melting of the hot reduced iron in a melting furnace optionally equipped with a scrap pre-heating station wherein part of the gases emerging from the reduction furnace are  
25 recircled to pre-heat iron scrap either directly in contact with the scrap after having effected the combustion of the residual CO and H<sub>2</sub>, or sent to burners as poor fuel or possibly enriched with gassy hydrocarbons, suitable to pre-heat the scrap.

30 The iron scrap constitutes all or part of the load of a melting furnace, for example an electric arc furnace, for the production of steel.

One purpose of this invention is to achieve a method and

relative plant which will exploit the energies to the maximum to obtain the minimum consumption possible in the process of producing steel starting from mineral iron, with a direct reduction of the scrap in a gravitational-type furnace.

The mineral iron, of various granulometry, is brought into contact with a feed gas in a vertical furnace of the gravitational or shaft type, wherein both the gas and the material are fed continuously, so that there is a flow of material from the top to the bottom and the direct reduction of the mineral is achieved. The material may be discharged from the reactor either cold or preferably hot to be sent subsequently to a melting furnace or so that it may be converted into hot briquette iron (HBI) or cooled and converted into direct reduction iron (DRI).

The reduction furnace is equipped with means to feed the mineral iron and means to discharge the reduced metallic iron; it is equipped with at least one inlet collector, arranged laterally, to inject the reducing gas in correspondence with one or more reduction zones inside the furnace.

The reduction gas sent into the reactor contains hydrocarbons injected into the current after the partial combustion of the hydrogen and carbon monoxide with the oxygen.

The direct reduction of the iron oxides is achieved in one or more continuous stages inside the reduction reactor.

Moreover, the inlet temperature of the two currents of reducing gas can be independently regulated by injecting O<sub>2</sub> before they enter the reduction reactor.

Whether there is a single inlet or multiple inlets, for example two, the flow of reducing gas can be regulated autonomously and independently, both in delivery and in

composition, since there is an addition of oxygen to raise the temperature and generate a change in the level of oxidation of the gas, from normal values of 0.04-0.08 to 0.06-0.15.

- 5 The following ratio is intended for the level of oxidation of the reducing gas:

$$\text{Nox} = (\text{H}_2\text{O} + \text{CO}_2) / (\text{H}_2\text{O} + \text{CO}_2 + \text{H}_2 + \text{CO})$$

- 10 The method also provides to inject natural gas into the current of gas entering the furnace to compensate the greater oxidation of the gas and in such a manner as to cause the reduction reaction of the iron oxide with gassy hydrocarbons such as  $\text{CH}_4$  and higher hydrocarbons in the inner zone of the reduction furnace containing metallic iron with the iron oxides.

- 15 Moreover, the inlet temperature of the current of reducing gas can be independently regulated by injecting  $\text{O}_2$  before it enters the reduction reactor with a final inlet temperature of more than  $760^\circ\text{C}$  preferably between  $900^\circ\text{C}$  and  $1150^\circ\text{C}$ .

- 20 The reducing gas enters the median zone of the furnace and acts in such a way as to cause the reduction reaction of the iron oxides to metallic iron.

The gas emerging from the reduction reactor is partly recircled and partly used as fuel.

- 25 The recircled gas has a volume composition within the following fields:

$\text{H}_2=20-41\%$ ,       $\text{CO}=15-28\%$ ,       $\text{CO}_2=15-25\%$ ,       $\text{CH}_4=3-10\%$ ,  
 $\text{N}_2=0-8\%$ ,       $\text{H}_2\text{O}=2-7\%$ .

- 30 Therefore, the recircled gas has a latent heat of reaction which can be exploited to improve the melting times of the scrap and to increase the total steel productivity. This energy can be modulated according to the production or processing requirements of the furnace so that the gas can be used to pre-heat the scrap in a variable quantity,

modulating it also according to the energy requirements of the reformer.

The recircled gas, containing CO and H<sub>2</sub>, is burnt in appropriate burners located in the scrap pre-heating station, preferably in a cover placed above the basket containing the scrap itself, so that the emerging gases, prevalently consisting of CO<sub>2</sub> and H<sub>2</sub>O, exchange energy through convection and radiance. The final temperature of the scrap depends on the cycle time of the furnace and the stratification of the scrap as well as on the quantity of gases used, and is between 300°C and 1000°C.

The melting furnace can thus be fed continuously with hot metallic iron; at the same time the gases emerging from the furnace are mixed, either wholly or in part, with the gases emerging from the burners and are used for pre-heating the scrap.

The recircled gas can be used as fuel for the burners of the melting furnace.

The fumes of the melting furnace, with a high CO content, can be used in cooperation with the reduction gases arriving from the reformer, in the pre-reduction zone of the reduction furnace, to pre-heat and pre-reduce the iron oxides.

In the case that the reduction gas enters the furnace from at least two side inlets, the direct reduction of the iron oxides is achieved in two different contiguous stages inside the reduction reactor.

In a first stage, defined as the pre-heating and pre-reduction stage, the fresh iron oxides, that is, those just introduced into the furnace, come into contact with a mixture of reduction gas, consisting of partly burnt gas, arriving from the underlying part of the furnace and of fresh hot gas, that is, gas introduced from outside,

arriving from a collector which brings fresh reducing gas and possibly  $\text{CH}_4$  or other natural gas. This first stage takes place in a corresponding first zone arranged in the upper part of the furnace.

- 5 In the second stage, or real reduction stage, the complete reduction of the iron oxides is achieved, due to the action on the oxides, already partly reduced in the first stage, of a mixture of reducing gas based on  $\text{H}_2$  and  $\text{CO}$  and at least a hydrocarbon, preferably natural gas, injected in the median  
10 zone of the reduction reactor. This second stage takes place in a corresponding second zone arranged below the first zone.

The first inlet for the reducing gas is located at a set distance (x) with respect to the second inlet, which is  
15 located in the median part of the furnace, in correspondence with the second reduction zone. This distance (x) is suitably between 1 and 6 meters, preferably between 2 and 4 metres, to encourage the reactions in the most suitable zone between the reducing gas and the iron oxides.

- 20 The first gas inlet also has the function of pushing the gases arriving from the second reduction zone towards the centre of the furnace so as to create a uniform distribution of the gas in the section of the reactor.

In This way, moreover, the iron oxides arrive at the  
25 reduction zone already partly reduced, thus encouraging the completion of the final reduction reaction from  $\text{FeO}$  to  $\text{Fe}$ .

According to another characteristic of the invention, the lower outlet of the furnace is of the multiple type, to allow the simultaneous discharge of several types of  
30 product.

The multiple outlet encourages the distribution of the reduction gas inside the furnace and a better distribution of the material inside the furnace, preventing preferential



channels which occur in furnaces with a single cone outlet.

In fact, in furnaces with a single cone outlet, the finer material tends to settle in the middle and this encourages the reducing gas to flow in the outer part, reducing the iron oxides nearer the wall more than in the middle; the reducing gas therefore has difficulty in penetrating the core of the solid bed of material, so that it is more difficult to reduce the iron oxides and in any case it takes longer.

10 The whole reaction zone of the furnace works with a more uniform and especially constant temperature along the whole section of the reduction furnace, encouraging a higher reaction speed, consequently reducing consumption and increasing productivity.

15 The flexible use of the extractors, to vary the outlet delivery, prevents the formation of bridges in the furnace.

The reduced metallic iron is discharged preferably hot through the multiple outlet, preferably with 3 or 4 cones, which are enabled to discharge the material in a controlled manner, independent of each other.

20 The great advantage of being able to discharge simultaneously from several points is that it is possible to regulate the outlet delivery of material by varying the speed of removal of the individual discharge systems.

25 Another advantage is that this movement helps to make the material descend from the upper zone in a uniform manner, with a perfect mixing of the larger particles with the finer particles, creating a continuous movement of the material and reducing the possibility of blockages of the material.

30 A further, considerable advantage is that it is possible to simultaneously discharge hot material which will then be used in various ways: one part may be introduced directly into a melting furnace, for final melting; a part may be

- 8 -

made into briquettes; and a part may be cooled outside in a silo and sent for storage.

A further advantage is that it is possible in any case to discharge all the output hot material into the melting  
5 furnace to produce steel, greatly reducing energy consumption.

All the material may also be briquetted hot or cooled and stored.

Unlike conventional furnaces equipped with a single  
10 outlet, the fact that there may be several outlets also makes possible to empty the furnace in the event that one of the outlets is blocked. In this case it is possible to act on the other outlets to almost completely empty the furnace, except for the part of the cone with the blocked outlet;  
15 once the rest of the furnace has been emptied it is possible to do maintenance operations more easily, and to unblock the material. This operation is not possible in conventional furnaces.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 These and other characteristics of the invention will become clear from the following description of a preferred form of embodiment, given as a non-restrictive example with the aid of the attached Figures wherein:

Fig. 1 shows in diagram form a plant for the production of  
25 steel starting from mineral iron according to the invention;

Fig. 2 is an enlarged detail of a variant of a reduction furnace employed in the plant shown in Fig. 1.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

30 With reference to Fig. 1, a plant for the production of steel according to the invention comprises a reduction furnace 10 of the vertical gravitational, or shaft type, inside which there is a reduction reactor. The furnace 10,

- 9 -

comprises in turn an upper mouth 11 for feeding from above, through which the mineral, consisting of iron oxides, is able to be introduced, a first pre-heating and pre-reduction zone 12, a second zone, or median zone 14 wherein the final  
5 reduction reaction of the iron oxides takes place, and a lower zone, or discharge zone 15.

The lower zone 15 consists of three ends, shaped like a cone or truncated cone tapering downwards 15a, 15b and 15c, each of which is provided with a lower aperture 16a, 16b and  
10 respectively 16c, through which, selectively, the directly reduced metallic iron (DRI) can be discharged in a controlled and independent manner.

The iron-based metal oxides are introduced into the reactor 10 in the form of pellets or crude mineral in the  
15 appropriate sizes; the iron contained therein is usually between 63% and 68% in weight.

At the end of the process according to the invention, the iron contained in the reduced material exiting from the reactor 10 is normally between 80% and 90% in weight.

20 In correspondence with the two zones 12 and 14 of the reactor 10 there are two independent inlets 17, respectively 18, through which a mixture of gas is suitable to be introduced, as will be described in greater detail hereafter.

25 In its upper part, above zone 12, the reactor 10 is provided with an aperture 19 through which the burnt gas exits. This gas normally has the following characteristics: composition:  $H_2=20-41\%$ ,  $CO=15-28\%$ ,  $CO_2=12-25\%$ ,  $CH_4=2-10\%$ ,  $N_2=0-8\%$ ,  $H_2O=2-15\%$ ; temperature between  $500^\circ C$  and  $700^\circ C$ ;  
30 oxidation level between 0.3 and 0.50, preferably between 0.40 and 0.45; and a reduction ratio R of between 1 and 1.8 where reduction ratio is taken as:

$$R = (H_2 + CO) / (H_2O + CO_2).$$

The burnt gas emerging from the reactor 10 is sent through a pipe 20 to a cooling unit 21, suitable to recover the sensitive heat; from the cooling unit 21, through another pipe 22, it arrives at a cooling and condensing unit 24. In this unit 24 the burnt gas is washed in water at a temperature of between 40°C and 65°C and the quantity of water present in the gas itself is partly removed. The percentage of water remaining in the gas at outlet from the unit 24 is between 2% and 7%.

10 The gas at outlet from the unit 24 is sent through a pipe 30 partly to a pre-heater 36, partly to a reformer 44, to be used as fuel, and partly to a compressor 26.

The gas emerging from the compressor 26 is in turn used partly as a recircled gas and sent, through a pipe 28, inside the unit 21, and partly, through a pipe 46, mixed with a natural gas, for example methane arriving from a pipe 34 in a proportion of about 4:1 (that is to say, for every part of natural gas there are about four parts of gas arriving from the pipe 46) and introduced into the reformer 44 so that the reforming reaction of the methane ( $\text{CH}_4$ ) with  $\text{H}_2\text{O}$  and  $\text{CO}_2$  can begin.

The part of gas which is sent to the unit 21 through the pipe 28 is pre-heated, and is then sent through a pipe 32 to the pre-heater 36, where it is further pre-heated to a temperature of between 650°C and 950°C.  $\text{CH}_4$  may also be injected into the pipe 32.

The gas emerging from the pre-heater 36, which has a delivery rate of between 600  $\text{Nm}^3/\text{ton}$  DRI and 1500  $\text{Nm}^3/\text{ton}$  DRI, is mixed in a pipe 38 with the gas arriving from the reformer 44 through a pipe 50.

The gas resulting from this mixture is divided into two parts and distributed into two pipes 40 and 41, connected to the inlets 17 and 18 of the furnace 10. Into each pipe 40

and 41 air is injected, or air enriched with oxygen or pure oxygen and natural gas in variable percentages. The delivery of reducing gas is controlled in each zone 12, 14 by means of regulation valves 85 and 86.

5 A current of  $\text{CH}_4$  or natural gas is injected into the gas before it is introduced into the reactor.

In a variant, shown by a line of dashes in Fig. 1, the  $\text{CH}_4$  is injected before achieving the partial combustion, with the purpose of raising the temperature of the gas introduced  
10 into the reactor.

The  $\text{CH}_4$  may also be introduced in a zone between the reduction zone 14 and the discharge cone of the material, through a pipe 81. In this case, before entering into the zone 14 where the reduction reactions are carried out, the  
15  $\text{CH}_4$  injected partially cools the reduced iron, before the latter is discharged.

Valves V1-V12 are located in correspondence with the different conduits of the plant so that the flow can be selectively controlled.

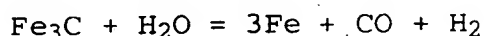
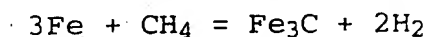
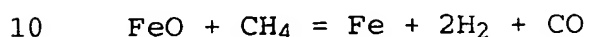
20 The resulting mixtures are introduced into the pre-heating and pre-reduction zone 12 and respectively into the reduction zone 14. Therefore, for each zone 12 and 14 the corresponding mixture of gas is regulated in an autonomous and independent manner, and according to the temperature of  
25 the reducing gas.

To be more exact, the flow of gas in the first zone 12 is between  $500 \text{ Nm}^3/\text{ton DRI}$  and  $800 \text{ Nm}^3/\text{ton DRI}$  and enters the reduction reactor 10 with a temperature of between  $800^\circ\text{C}$  and  $1150^\circ\text{C}$ , preferably between  $1000^\circ\text{C}$  and  $1150^\circ\text{C}$ , while the flow  
30 of gas in the second zone 14 is between  $1000 \text{ Nm}^3/\text{ton DRI}$  and  $1500 \text{ Nm}^3/\text{ton DRI}$  and enters the reduction reactor 10 with a temperature of between  $800^\circ\text{C}$  and  $1150^\circ\text{C}$ , preferably between  $1000^\circ\text{C}$  and  $1150^\circ\text{C}$ .

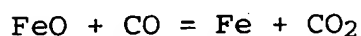
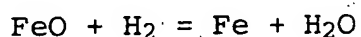
The consumption of oxygen, which is necessary to raise the temperature of the reducing gas from 650°C-950°C to 800°C-1150°C, intended as pure oxygen plus that contained in the air, if air is also injected, is between 8 Nm<sup>3</sup>/ton DRI and 60 Nm<sup>3</sup>/ton DRI, preferably between 20 and 60 Nm<sup>3</sup>/ton DRI.

The consumption of CH<sub>4</sub> is between 50 and 120 Nm<sup>3</sup>/ton DRI, preferably between 90 and 110 Nm<sup>3</sup>/ton DRI.

The reactions involved in the reduction zone 14 are as follows:

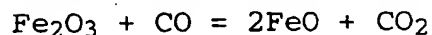
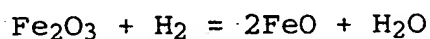


Simultaneously, in the same zone 14, the following reduction reactions take place with hydrogen and carbon monoxide:



The consequence of these endothermic reactions is that the temperature of the gas in the reduction zone decreases from 800°C-1150°C to 700°C-900°C, yet still maintains the reaction temperature higher than in furnaces in the state of the art, and the gas leaving the reduction zone 14 has an oxidation level of between 0.15 and 0.35 and a reducing power of between 1.1 and 2.8.

25     The reactions involved in the pre-reduction zone 12 are as follows:



In the lower zone 15, shaped like a truncated cone, it is also possible to introduce gas containing natural gas to control the final carbon in the hot reduced iron to values of between 1.5% and 3.0%.

According to one characteristic of the invention, the

recircled gas, which possesses a latent heat of reaction, is also exploited to improve the melting times of a station 60 to pre-heat iron scrap and increase the total steel productivity. This energy can be modulated according to the  
5 production or processing requirements of the furnace, so that the gas can be used to pre-heat the scrap in a variable quantity, modulating it also according to the energy requirements of the reformer 44.

To be more exact, the pipe 46 is connected by means of  
10 valves 70 to the following elements: the burners 66 of the scrap pre-heating station 60, to which burners 66 a fuel and, respectively, air and oxygen also arrive through pipes 67 and 68; the burners 62 of the melting furnace 51; a mixer-heater 69, connected in turn with the scrap pre-  
15 heating station 60. A fuel and, respectively, air and oxygen flow into the mixer-heater 69 through pipes 71 and 72.

In this way, the recircled gas, containing CO and H<sub>2</sub> is burnt in burners 66 of the scrap pre-heating station 60, preferably in a cover 75 located above the basket containing  
20 the scrap, so that the emerging gases, prevalently consisting of CO<sub>2</sub> and H<sub>2</sub>O, exchange energy through convection and radiance. The final temperature of the scrap depends on the cycle time of the furnace and the stratification of the scrap, as well as the quantity of gases used, and is between  
25 300°C and 1000°C.

The directly reduced metallic iron (DRI) emerges hot from the furnace 10, at a temperature of between 600°C and 800°C and can follow either of the three ways 15a, 15b or 15c.

In this way, for example, one part can be introduced  
30 directly into a melting furnace 51, such as an electric arc furnace, for final melting, provided with an outlet 63 from which the steel is removed; a part can be briquetted by a briquetting machine 52; and a part can be cooled outside in

a silo 53 and sent for storage. In turn, the part emerging from the silo 53 can also be sent to the electric furnace 51.

The electric furnace 51 can thus be fed continuously with  
5 hot metallic iron.

The gases emerging from the furnace 51 are all mixed together or partly with the gases emerging from the burners 62 and, by means of a pipe 76, are used in the pre-heating of the scrap in the station 60.

10 The pipe 76 is also connected, by means of a pipe 61, to the pipe 40 which takes the reducing gas to the zone 12 of the reduction furnace 10. A filter device 90 is inserted in the pipe 61 to separate and retain any possible powders included in the fumes.

15 The fumes from the melting furnace 51, in fact, have a high CO content, and can be used in cooperation with the reduction gases arriving from the reformer 44, in the pre-reduction zone 12 to pre-heat and pre-reduce the iron oxides.

20 According to a variant of the furnace 10, as shown in Fig. 2, each lower end 15a, 15b and 15c is provided with a rotary valve 47, 48 and respectively 49, suitable to regulate the flow of material emerging from the furnace 10.

Moreover, each lower end 15a, 15b and 15c is provided with  
25 an inlet 55 through which a cooling element can be introduced; hence, from the outlets 16a, 16b and 16c hotter or cooler products can emerge or even already cooled enough to be stored immediately.

Each lower end 15a, 15b and 15c can also be provided with  
30 a device 56 to inject fuel gas to have different levels of carbon in the reduced iron at outlet, according to the use which will be made thereof.

Obviously, it is possible to make modifications and



- 15 -

additions to the method for direct reduction of mineral iron and the relative plant as described heretofore, but these will remain within the field and scope of the invention.

- 16 -

## CLAIMS

- 1 - Method for the production of steel starting from mineral iron, wherein the iron is present in the form of oxides, comprising the following steps: the mineral iron is fed into  
5 a vertical reduction furnace (10) of the type with a gravitational load, a mixture of high temperature gas is injected into the reduction furnace (10), the directly reduced iron (DRI) is removed from the reduction furnace (10), and the directly reduced iron (DRI) is melted in a  
10 melting furnace (51), the method being characterised in that the directly reduced iron (DRI) goes to feed the melting furnace (51) directly and that at least a part of the recircled gases of the reduction furnace (10) is used in a station (60) to pre-heat the scrap or as fuel for burners  
15 (62, 66) or directly introduced into the scrap pre-heating station (60).
- 2 - Method as in Claim 1, wherein the reduction furnace (10) comprises means (15) to discharge the reduced metallic iron having at least two ends (15a-15c) each of which is provided  
20 with a corresponding lower aperture (16a-16c), through which the reduced metallic iron can be discharged in a controlled and independent manner, characterised in that the reduced metallic iron output from the lower apertures (16a-16c) is conveyed selectively to at least two distinct zones (51-53)  
25 downstream of the said ends (15a-15c), wherein one of the zones (53) is used to cool and temporarily store the reduced metallic iron and the other zones (51, 52) are suitable to use the hot load of the reduced metallic iron.
- 3 - Method as in Claim 1 or 2, characterised in that the  
30 reduced metallic iron is sent to a briquetting station (52).
- 4 - Method as in Claim 2, characterised in that the reduced metallic iron emerging from at least two of the lower apertures (16a-16c) is conveyed to the same zone downstream

of the said ends (15a-15c).

5 - Method as in Claim 2, characterised in that each of the ends (15a-15c) is suitable to be cooled selectively and independently from the other ends (15a-15c).

5 6 - Method as in Claim 2, characterised in that fuel gas is suitable to be selectively and independently injected into each of the ends (15a-15c) so as to have different levels of carbon in the reduced iron output from each end (15a-15c).

7 - Method as in any claim hereinbefore, characterised in  
10 that the mixture of reducing gas is introduced into at least two reaction zones (12, 14) arranged vertically distanced in the reduction furnace (10).

8 - Method as in any claim hereinbefore, characterised in  
15 that the mixture of reducing gas comprises at least a hydrocarbon, preferably natural gas, which is mixed before being introduced into the reduction furnace (10).

9 - Method as in Claims 7 and 8, characterised in that each hydrocarbon mixed with the reducing gas is proportioned and controlled independently in the different zones along the  
20 length of the furnace (10) into which it is injected.

10 - Method as in Claims 7 and 8, characterised in that the reducing gas, before being mixed with each hydrocarbon, is heated to a temperature of between 800°C and 1150°C.

11 - Method as in Claim 10, characterised in that the  
25 mixture of reducing gas is heated independently in the different zones along the length of the furnace.

12 - Method as in Claim 10, characterised in that the reducing gas is heated by making it partly interact with O<sub>2</sub>.

13 - Method as in Claim 7, characterised in that the  
30 delivery of the reducing gas is controlled in the different zones along the length of the furnace (10) in which it is injected.

14 - Plant for the production of steel starting from mineral

- iron, wherein the iron is present in the form of oxides, comprising a vertical reduction furnace (10) of the type with a gravitational load to achieve reduction and auto-reforming reactions of the mineral iron inside, feed means (11) to feed the mineral iron into the furnace (10) from above, means to inject a mixture of reducing gas inside the furnace (10), means to remove (15) the directly reduced iron (DRI) from the lower part of the furnace (10), and a melting furnace (51), the plant being characterised in that means are also provided to convey the directly reduced iron (DRI) directly to the melting furnace (51) and that pipe means (46) are provided to selectively take at least part of the recircled gases from the reduction furnace (10) to the burners (62) of the melting furnace (51).
- 15 15 - Plant as in Claim 14, characterised in that the pipe means (46) are provided to selectively take at least a part of the recircled gases from the reduction furnace (10) to the burners (66) of a station (60) to pre-heat scrap or directly inside the station (60) to pre-heat scrap.
- 20 16 - Plant as in Claim 14 or 15, characterised in that the reduction furnace (10) comprises means (15) to discharge the reduced metallic iron having at least two ends (15a-15c) each of which provided with a corresponding lower aperture (16a-16c), through which the reduced metallic iron can be
- 25 selectively discharged in a controlled and independent manner.
- 17 - Plant as in Claim 14, 15 or 16, characterised in that a briquetting station (52) is provided downstream of the reduction furnace (10) to receive at least part of the
- 30 reduced metallic iron (DRI).
- 18 - Plant as in Claim 16, characterised in that means are provided to convey the reduced metallic iron emerging from at least two of the lower apertures (16a-16c) to the same

- 19 -

zone downstream of the ends (15a-15c).

19 - Plant as in Claim 16, characterised in that cooling means (55) are provided to selectively and independently cool each of the ends (15a-15c).

5 20 - Plant as in Claim 16, characterised in that injection means (56) are provided to inject into each of the ends (15a-15c) fuel gas to have different levels of carbon in the reduced iron output from each end (15a-15c).

10 21 - Plant as in any claim from 14 to 20 inclusive, characterised in that means (17, 18) to introduce the mixture of reducing gas are arranged in at least two or more reaction zones (12, 14) arranged vertically distanced in the reduction furnace (10) to achieve the reduction and auto-reforming reactions in a controlled manner.

15 22 - Plant as in any claim from 14 to 21 inclusive, characterised in that means to mix the reducing gas with at least a hydrocarbon, preferably natural gas, are suitable to mix the reducing gas before it is introduced into the reduction furnace (10).

20 23 - Plant as in Claims 21 and 22, characterised in that means are provided to proportion and control each hydrocarbon mixed with the reducing gas, in an independent manner, in the different injection zones on the length of the reduction furnace (10).

25 24 - Plant as in Claim 21 and 22, characterised in that means are provided to heat the reducing gas to a temperature of between 850°C and 1150°C before being mixed with each hydrocarbon.

30 25 - Plant as in Claim 24, characterised in that the reducing gas is heated independently in the different zones along the length of the reduction furnace (10).

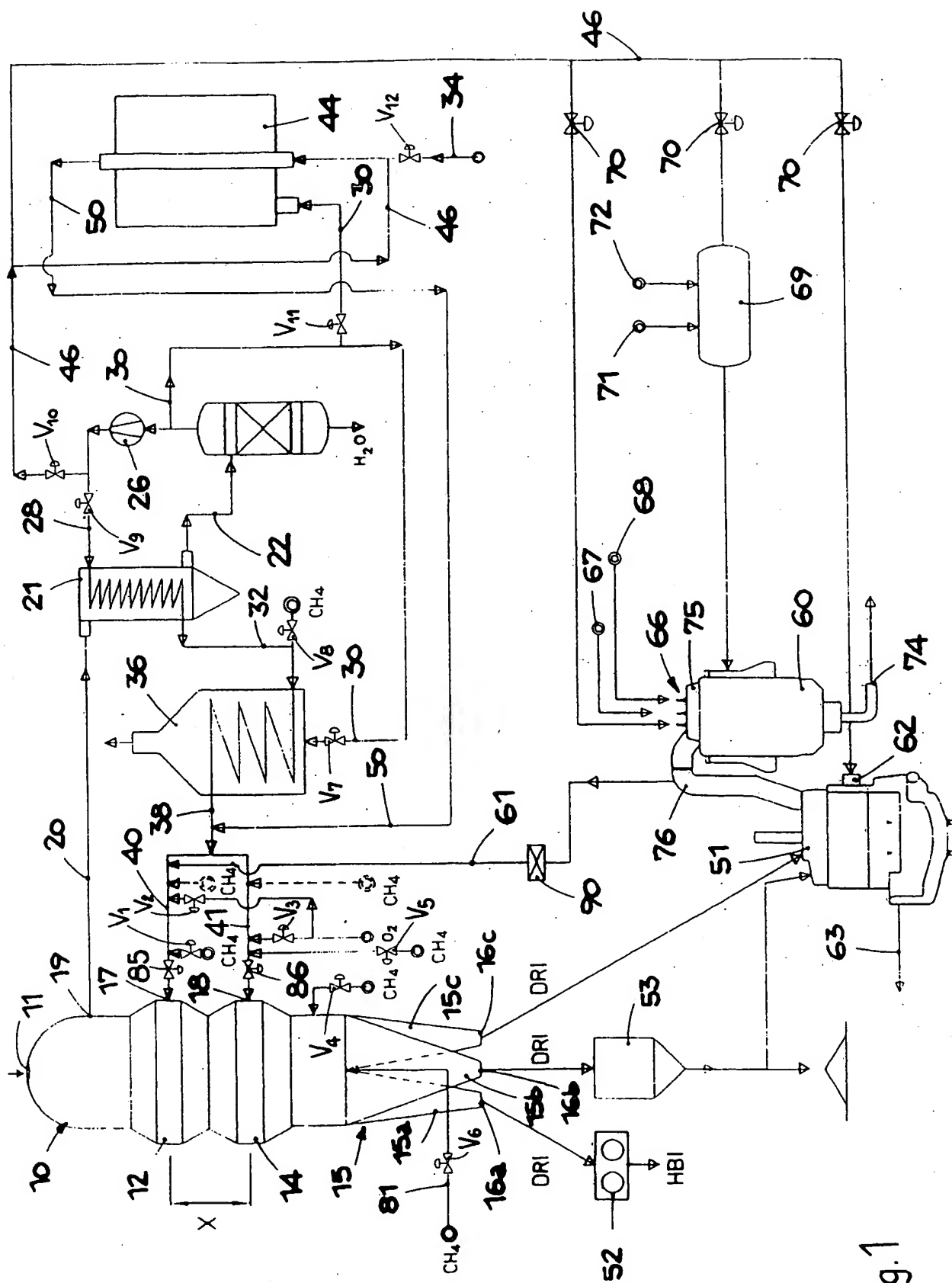
26 - Plant as in Claim 24, characterised in that the reducing gas is heated by making it react partly with O<sub>2</sub> or

- 20 -

air enriched with O<sub>2</sub>.

27 - Plant as in Claim 21, characterised in that regulation means (85 and 86) are provided to control the delivery of the reducing gas in the different injection zones (12, 14) along the length of the reduction furnace (10).

28 - Plant as in Claim 16, characterised in that each of the lower apertures (16a-16c) is provided with rotary valve means (47, 48, 49) to regulate the flow of the reduced iron from the reduction furnace (10).

$\frac{1}{2}$ 

2/2

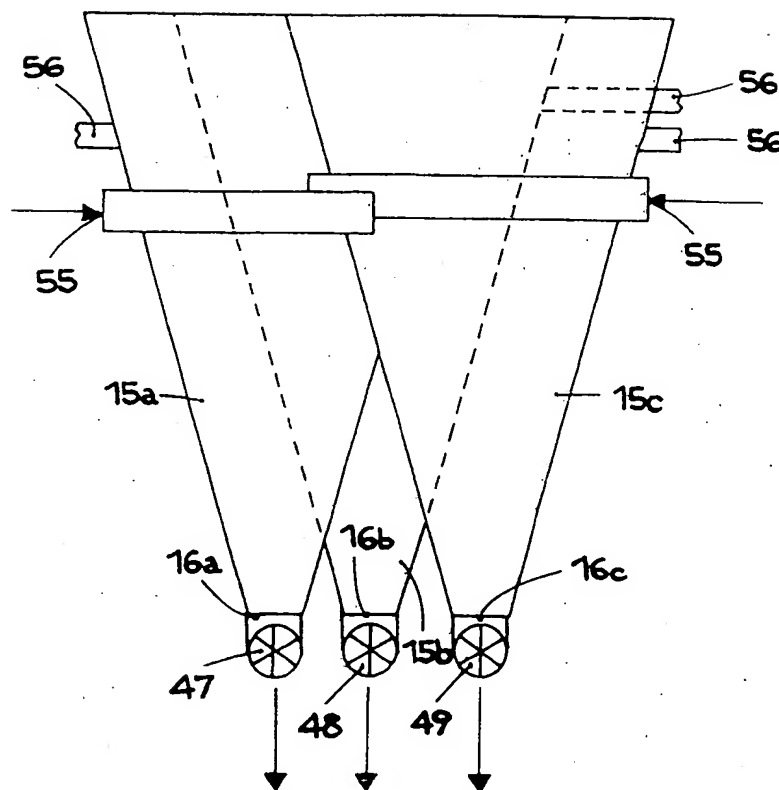


fig. 2



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 99/01924

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C21B13/14 C21B13/02 C21B13/04

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C21B F27D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 40 41 689 A (ORINOCO SIDERURGICA) 24 October 1991 (1991-10-24)	1,3,8, 14,16, 17,22
A	abstract  column 1, line 26 -column 3, line 6 column 3, line 32 -column 4, line 5 column 4, line 65 -column 5, line 30 claims 1,2,10,11,14,15,17-21; figure --- -/--	2,7,9, 10,15, 21,23,24

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

8 February 2000

Date of mailing of the international search report

16/02/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Ceulemans, J

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 99/01924

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 725 309 A (MACKAY PATRICK W ET AL) 16 February 1988 (1988-02-16)	1,3,8, 14,16, 17,22 2,7
A	abstract column 1, line 6 - line 18 column 2, line 41 - line 45 column 3, line 51 - line 68 column 4, line 13 - line 26 claims 1-3,12,13,16,17,20; figure 1 ----	
A	US 4 826 429 A (NIEMS LEE H) 2 May 1989 (1989-05-02) ----	2
A	US 4 270 739 A (AHRENDT WILLIAM A ET AL) 2 June 1981 (1981-06-02) cited in the application the whole document -----	2,7-13, 21-27

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/IB 99/01924

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 4041689 A	24-10-1991	US 5069716 A	03-12-1991
		CA 2039940 A	21-10-1991
		GB 2243840 A,B	13-11-1991
<hr/>			
US 4725309 A	16-02-1988	AU 585798 B	22-06-1989
		AU 7001887 A	24-09-1987
		BR 8701190 A	19-01-1988
		CA 1290573 A	15-10-1991
		CN 1010955 B	26-12-1990
		DE 3781923 A	05-11-1992
		EP 0241732 A	21-10-1987
		IN 169323 A	28-09-1991
		JP 1029850 B	14-06-1989
		JP 1546895 C	28-02-1990
		JP 63000410 A	05-01-1988
		MX 165679 B	25-11-1992
		SU 1634141 A	07-03-1991
<hr/>			
US 4826429 A	02-05-1989	US 4728288 A	01-03-1988
		DE 3743397 A	28-07-1988
		DK 672987 A	09-09-1988
		NO 875367 A,B,	23-06-1988
<hr/>			
US 4270739 A	02-06-1981	BE 885802 A	16-02-1981
		BR 8006729 A	22-04-1981
		CA 1152750 A	30-08-1983
		DD 153701 A	27-01-1982
		DE 3039838 A	14-05-1981
		FR 2467884 A	30-04-1981
		GB 2062686 A,B	28-05-1981
		JP 56077308 A	25-06-1981
		MX 154673 A	18-11-1987
		SU 978735 A	30-11-1982
		US 4333761 A	08-06-1982
		ZA 8006425 A	28-10-1981